Thermal Comfort for Passive dwellings via Optimum Roof Architecture (RoofOpt)

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ABSTRACT

The occurrence of hot discomfort during the daytime is a serious problem for the citizens living in tropical regions. This drove the citizens to look intently on thermal comfort conditions. In tropical regions, the most prominent component that affects thermal comfort is the roof architecture as roofs are exposed to direct solar radiation. Conversely, in the modern world the houses are influenced by modern architecture where, the designer only concentrates on the aesthetic side of the dwelling. Therefore, to avoid thermal discomfort, designers use their experience, knowledge to determine a better dwelling structure through different passive methodologies. But professionals very rarely realize that the current passive techniques will result in a satisfactory solution to the dweller.

This paper presents a framework that will provide an intelligent artifact which will determine the optimum roof architecture according to thermal comfort conditions in a dwelling. The proposed system consists of three layered architecture and consists of five main components. Each major component is further divided into sub modules. Data Extractor (DE),User preference component (UPC),Case based reasoner(CBR) ,Fuzzy decider (FD) component and Two dimensional designer components (2DDesign).This software tool promotes the concept of "Thermal Comfort", a novel, easy to use, intelligent can be used to obtain the optimum roof architecture, insulation material and thickness in tropical climatic conditions.

1.0 INTRODUCTION

Warm humid climatic conditions prevail in many parts of the world. This climate is experienced in populous regions in South and Central America, South Asia, South- East Asia and Africa. In such regions experiencing warm humid climate conditions, hot discomfort is one of the major problems in houses and buildings [1].

Generally, the tropical climatic countries have a high population density. Most of these countries still remain as developing countries. With the economic development, the energy consumption for thermal comfort is also rising.

However, in recent times, a new trend has emerged in the housing sector due to the influence of modern architecture. This adverse situation is further deteriorated by adopting various features for houses and buildings that would be more suitable for temperate climates. Many designers in this region have ignored the climate in their designs, primarily because they are pre-occupied with fashionable building forms. They have tried to separate the building from nature rather than integrate it. Once separated, indoor thermal comfort should be achieved using air-conditioners, fans etc. These will require considerable amount of energy for operation resulting in high cost to the dweller and the country as a whole. This is not a desirable situation for most of these countries, which are still in the developing stage. Therefore, it is an essential fact that when designing dwellings, the designer should give due consideration to comply with nature to achieve thermal comfort by maximizing the natural sources.

Currently, architects/designers use their experience to design the appropriate roof architecture and insulation thickness/material for a particular building. Mostly, a great effort is spent on

- Deciding the optimum combination of the roof parameters
- Deciding the appropriate insulation thicknesses & materials for a particular dwelling to achieve thermal comfort.

Because of the unstructured, heuristic nature of this method, that is

- There is no proper calculation formulae available to determine the appropriate insulation thicknesses based on climatic factors.

- There is no proper algorithm to determine the thermal comfort for a combination of roof parameters

Optimum roof architecture, appropriate thickness, thermal performances, energy consumption and budget cannot be scientifically determined.

Thus, comes a need for a better software tool, to "design thermal comfort dwellings". There have been numerous attempts found to designing low energy dwellings and thermal comfort dwellings. RESFEN 2.1 [2], Building Design Advisor [3], ASHRAE Thermal Comfort Tool [4], DEROB-LTH [5] etc are some of the commercial applications found in the market today. Most of these concentrate on energy consumption, low energy or thermal comfort achieved to measure hypothetical human at a point in space through mathematical calculations, algorithms/ simulations etc. These applications are specifically design to cater to the cold climates like USA, Europe etc. In order to provide optimum solution, reasoning the answer, provide alternative solutions an intelligent tool has to be devised.

Continuous increase in computational power has encouraged the development of software tools in many different fields such as medical, automotive, finance etc. During the research carried out, it was revealed that the underlying concept has only been confined as a theoretical fact. It has not been practiced in real life scenarios in Sri Lanka. Dealing with changing climatic conditions, managing enormous amount of data and performing mathematical calculations are impossible tasks to a normal human being. As a result, lack of practical exposure to the phenomenon "Thermal Comfort" is minimal. In order to approach the architectural community, an artifact should be devised to guide the architects, designers, to achieve thermal comfort in their architectural presentations and expose the professionals to take up this phenomenon to the architectural community. It is important to note that there is no proper tool designed to decide on optimum solutions, provide alternative solutions and weigh the pros and cons of solutions offered in this field of architecture.

2.0 PROBLEMS IN DESIGNING OPTIMUM ROOF ARCHITECUTRE AND DECIDING APPROPRIATE THERMAL INSULATION MATERIALS

In designing optimum roof architecture and appropriate reflective/ resistive insulation materials for a particular dwelling situated in a particular region or zone [6] is a problematic issue in many facets. Many problems associated in deigning can be overcome successfully by incorporating complex expert knowledge/ experience, experimental results and importantly natural resources such as sunlight, ventilation and humidity. Great emphasis was carried out on acquiring proper and accurate expert knowledge also their experimental results. Not only expert information, climatic information was obtained in order to analyze the thermal comfort values per region and to obtain its comfort zones [6]. The research in gives and account for the strengths and weaknesses of software tools that have been practiced in the architectural world.

In order to deal with expert knowledge, climatic information and also to obtain optimum results, alternative results according to thermal comfort levels, budget etc are needed to comply to devise an artifact which can emulate expert intelligence. We now summarize some of the more important issues highlighted therein which are also relevant to our discussion as well.

A. O*btaining proper Roof parameters.* When designing a proper, optimum roof according to thermal comfort levels, budget, land information etc, quite a large amount of parameters are affected. For an example, orientation, roof shape, roof angle, roof materials, ceiling materials, ceiling shape etc are affected [7]. Deciding different roof architectures are classified among the dwelling types, new dwellings or existing dwellings.

B. *Acquiring the thermal comfort information per region.* This is one of the most important and a critical task. Because of its complexity in obtaining comfort regional climate details [6]. This is mainly achieved by capturing maximum and minimum temperatures, humidity and air velocity in a particular region. These details will be directly fed in to the pho…….. Graph [8] to produce comprehensive information on thermal comfort temperature, humidity and appropriate air velocity.

C. *Use of Artificial Intelligence techniques*
According to the research carried out, revealed that most of the software tools use mathematical techniques to provide direct solutions for the user. It not appropriate in determining the optimum solution or alternative solutions and reasoning each solution and most importantly dealing with climatic conditions. Designing roof architectures based on thermal comfort conditions, budget etc need expert knowledge/ experience. Therefore, using artificial

intelligence techniques would be ideal method to deal with the problem.

D. *Tackling optimum roof architecture.* Mostly, a great effort is spent on deciding the optimum combination of the roof parameters for a particular dwelling to achieve thermal comfort. To decide on the optimum architecture, genetic algorithm [9] or case base reasoning [10] can be incorporated. Choosing the appropriate AI technique was a challenging task.

E. *Tackling appropriate thermal insulation materials.* Before deciding the proper insulation [11] thickness, the professional have to be aware on the climatic parameters that are being inspected. There are many factors involved such as the room temperature, roof temperature, humidity, air velocity, no of levels in a dwelling, the existing roof material etc. Based on these factors a proper insulation thickness [12] has to be devised per room in a dwelling. Because comfort varies from one part to another in a dwelling. Therefore, proper insulation material layout has to be manufactured.

From the above discussion we infer the following conclusions.

A. Proper roof parameters have to be obtained in order to present the optimum results according thermal comfort conditions. Along with the results heating loads, or any extra features added have to be displayed. Assumption: Only four types of Roof shapes have been built-in, in the **RoofOpt** prototype.
B. In order to obtain the optimum results, alternative along with the reasons case base reasoning AI technique have to be used. Because, past expert experience/knowledge is being inferred.
C. To decide on the proper thermal insulation thickness for a particular dwelling per room, including changing climatic information and professional experience, Fuzzy logic AI techniques have to be used.

3.0 DESIGN OF XML GENERTATION

This feature has been designed to retrieve and process climatic information through XML files, which has made to extract updated climatic information from the meteorology department, if an EDI link exists.

This is mainly developed using "**System.XML**" inbuilt library in VISUAL .NET environment. The library will provide a mechanism to read information and write information in to the XML file where each climatic detail has to be written and read using **WriteXML** and **ReadXML** respectively. Details of these inbuilt types can be found in [13].
The construction of XML files will be explained in two different sections.

Write climatic details to the XML file:

The climatic information retrieved from the local database is fed in to a temporary Dataset through standard stored procedures.

Using the **System.Data** and **System.Data.SqlClient** libraries it was able to directly manipulate the database through prewritten stored procedures. The main concept of handling the climatic data stored procedure at the coding level was to gather climate information to the interface level which will be used to manipulate data retrieval, insert, delete and update at the database layer.

```
sqlCommand1.Parameters.Clear();
sqlCommand1.CommandType =
CommandType.StoredProcedure;

sqlCommand1.CommandText =
"SD_SP_GetClimateData";

SqlParameter ParaNum
=sqlCommand1.Parameters.Add("@RegNo",SqlD
bType.Char,10);
```

Figure 3.1 - Retrieve Climatic information from database tables

Through a Data reader each dataset parameter is written to a XML file. Following will portray the creation of the XML file using **XMLTEXTWRITER.**

```
XmlTextWriter writer = new
XmlTextWriter(@"F:\Softwareproject\Myfina
lyearproject\cbr\CBR_Tester\WritingUserIn
put.xml",null);
writer.Formatting = Formatting.Indented;
writer.WriteStartDocument();
writer.WriteStartElement("Query");
writer.WriteAttributeString("CID",id)
```

Figure 3.2 – Creating an XML file and start writing the document

Read Climatic details from XML file:

To retrieve data from an XML file, the method **XMLReader** [13] was used to reads each node at a time.

To recognize each node **XMLNodeType.Element** and **XMLNodeType.Attributestring** is used to read the value specified under that Node.

```
switch (Reader.NodeType)
{
   case XmlNodeType.Element:
   name = (Reader.Name);
    if (Reader.Name == "Query")
      {
        while
         Reader.MoveToNextAttribute()
         {
            SID = (Reader.Value);
      }
```

Figure 3.3 – Reading the XML file

For brevity, lengthy discussions related to the XML is avoided, more information can be found in [13].

4.0 DESIGN OF TWO DIMENSIONAL DRAWINGS USING GDI+

To achieve user friendliness in presenting information to the user, 2D designs were incorporated. GDI+ is quite a complex, challenging design library in constructing changeable designs (E.g.: When ever user changes roof details, design changes accordingly).For more information on GDI+, refer [14].

Visualize different roof shapes and insulation thicknesses to the designer, namespaces **System.Drawing.Drawing2D** and **System.Drawing** was incorporated. These namespaces provide basic shapes such a lines, rectangles, circles, pies etc. In order to design roof shapes in different angles, many complex mathematical equations have to apply on the mentioned basic shapes.

```
GraphicsPath myPath = new GraphicsPath();
Rectangle pathRect = new
Rectangle(181,198, 45,45);
myPath.AddRectangle(pathRect);
Pen myPen = new Pen(Color.Transparent,
2);
e.Graphics.FillPath(mySolidBrush,
myPath);
e.Graphics.DrawPath(myPen, myPath);
```

Figure 4.1 – Designing roof shapes using rectangles and pies.

```
Y = (referen - sweepAngle);
Z = (Y/5);
startAngle = System.Convert.ToInt64((Z *
2.5)+ referen);
}
else if (sweepAngle >= referen)
{
   Y = (sweepAngle - referen);
   Z = (Y/5);
   startAngle =
System.Convert.ToInt64(referen -(Z*2.5));
}
```

Figure 4.2 – Drawing the roof shapes according to the specified angles.

5.0 DESIGN OF MICROMEDIA FLASH TWO DIMENSIONAL DESIGNS

This concept of designing in macromedia flash allows the user to portray the optimum results obtained in the form of a graphical representation of the overall roof architecture. Presentation of roof materials, insulation materials and ceiling materials along with the roof design is created using Macromedia flash MX and Active Server [15].

This was developed using *action script* [15] and designs are generated in movie files.

Manipulating values obtained from the program are stored in action variables. Images and shapes are stored as objects, which are manipulated according to the variable values specified and place the shapes/images on the X, Y plane. During the analysis stage it was found that Flash cannot be extended to create 3D drawings. This can be incorporated in to the program by using Directive X in designing three dimensional Drawings.

```
setProperty(line, _height, hypo);
setProperty(line_r, _height, hypo);
setProperty(line_rb, _height, hypo);

line_r_x = getProperty(line_r, _x);
line_r_x_tem = ((line_r_x)+Number(length));
setProperty(line_rb, _x, line_r_x_tem);
```

Figure 5.1 – Sample from action script.
Movie files generation.

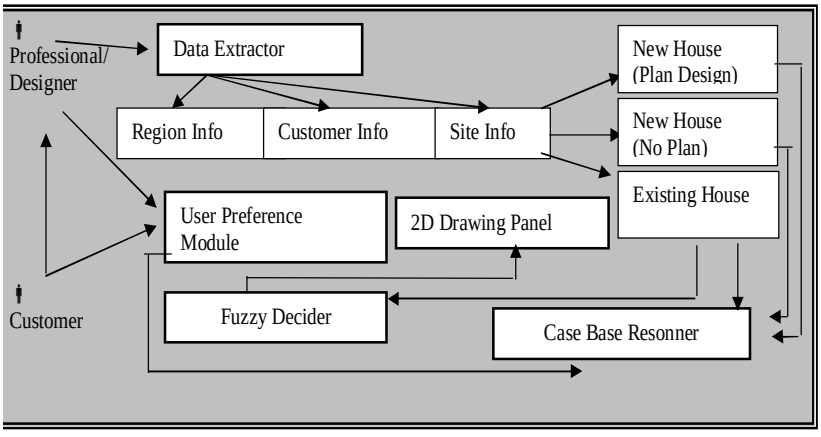
6.0 FUNCTIONAL BLOCK

In section 2.0 some of the key issues handled by designing the optimum roof architecture and insulations are highlighted. Investigations and surveys are carried out on existing applications and ongoing research discovered a new mechanism of solving the thermal discomforts using expert knowledge. The model mainly categorized and described under five major components.

- Data Extractor
- User Preference Module
- Fuzzy Decider
- Case Base Reasoner
- 2D Drawing Designer

Each Major Component will be sub divided into sub components which will be described and discussed in the next following section.

Fuzzy decider and the case base reasoner are the key components in the system which presents with the optimum results according thermal comfort condition as well as the climatic details obtain per room in a dwelling. Designer/professional will have to obtain climate data, customer requirements and site details through the **Data Extraction** component and then acquiring preferences /problem from the customer by the **User Preference** component. Customer requirements, roof architecture preferences details also thermal comfort, budget etc are fed in to **the Case Base Reasoner**. This in turn will present with the optimum roof architecture details. By Moving into the **Fuzzy Decider** a customer will be able to obtain an appropriate thermal insulation thickness per room in a dwelling.**2Dimensional designer** will portray the optimum roof details as well as insulation thicknesses in graphical format also in charts.



6.1 - Overall Functional Block Diagram

6.1 COMPONENT DESIGN

Each component is further divided into sub modules, where each module performs its task independently. Communication between each module will be handled through shared information.

6.1.1 Data Extraction

This particular module will be mainly targeted at gathering raw information from external sources such as regional & Climate Information from Meteorology department or from professionals, Customer Information & Dwelling Designs and finally Site Details gathered during the site inspection. Site Details will be then categorized into two sub modules, new Dwelling designs and Existing Dwelling designs.

- Climate Information
- Customer Information
- Site Information
  - New Dwelling Design
    - Plan available
    - Plan not available
  - Existing Dwelling Design

6.1.1.1 Climate Information

This particular feature is added to obtain climate information to calculate the thermal comfort per region. This will allow the professional/designer to directly retrieve thermal comfort values for particular customer site location. Here, it is able to extract climate data from XML file formats (if a direct connection is available with the Meteorology department) or professional will be able to enter information by key in data manually.

6.1.1.2 Customer Information

This will extract basic customer information like customer name, address etc while assigning a customer a unique identifier. Along with this information the professional/Designer should input, whether the roof is designed for a new house or an existing house. Depending on the type of category, he will be placed in the appropriate *site module*.

6.1.1.3 Site Information

This is one of the important sub modules, where most of the other major components will be accessed with in it. Site Information is categorized in to three sub components .For an example when a customer needs to obtain a solution for a existing house he will be able to access this particular form for the roof design solution. This sub module directly interacts

with the *Case Base Reasoner* and the *Fuzzy Decider* for appropriate solutions. The following sub modules will be discussed in wider context.

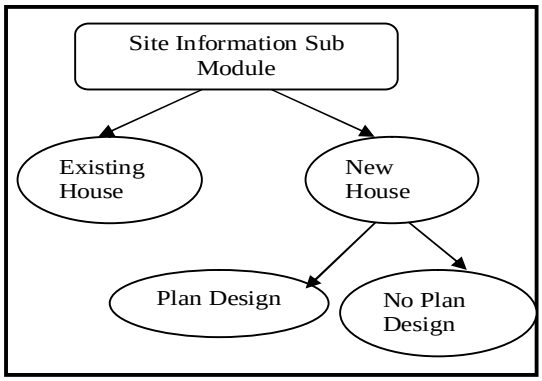


Figure 6.1.1.1 – Decomposition of Site Information Module

6.1.1.3. a Existing House Sub Module

This module will mainly target customers who need to find a comfortable roof through insulations or renovate his particular roof appropriately. When a professional visits to the particular site location he will be able to gather information such as the roof details of the existing house and the temperature, humidity. Air velocity levels of the existing house. These climatic conditions will be inspected in rooms that directly touch the roof.

6.1.1.3.b New House Sub Module (Plan available)

This module is one of the sub modules of the New House Module. This contains information about customer's who is willing to verify and design proper roof architecture according to the thermal comfort levels, budget and cooling, heating loads. This will offer the customer an opportunity to verify whether the drawn roof architecture provides adequate interior thermal comfort.

6.1.1.3.c New House Sub Module (Plan not available)

This module is mainly designed for the customer's who has no plan drawn prior to the construction a new house. It will allow the designer chose proper roof architecture according to the site location thermal comfort levels and customer preferences.

6.1.1.4 User Preference Module

This is one of the most important modules, which allows the user to specify roof architecture preferences and to verify whether it satisfies the thermal comfort levels, budget or the user requirements.

This module will be used in three specific areas.

1. In existing dwellings at the renovation stage - Will allow the user to key-in current roof architecture details to verify whether it meets the thermal comfort levels, user required budget and usage of insulations.
2. In New dwellings at the Construction stage - Will allow the user to key- in, roof architecture details specified in the plan to verify whether it meets the thermal comfort levels, user required budget and usage of insulations.

User desired stage (User preference) – Will allow the user to key-in, user preferred roof architecture details to verify whether it meets the thermal comfort levels, user required budget and usage of insulations

6.1.1.5 Fuzzy Decider

The fuzzy Decider will be designed only to the *existing site Information* sub module. This will extract climatic readings from a particular dwelling to decide the appropriate insulation thickness for each room in a dwelling. In order to decide on the appropriate insulation thickness, a *fuzzy module* has been designed, where it is governed using the **fuzzy logic principle** [16].

6.1.1.6 Case Base Reasoner

This particular module is directly linked to the *User preference module*. It will capture all the preference parameters into the *case base reasoning module*, where it will analyze the parameters with the case parameters. Each case in the database is weighted, based on the weights assigned at the user preference module. **Case base reasoner** is designed as an independent module. Based on the user criteria, the appropriate case base module will be overloaded. Weighted results will in turn transfer to the User *preference module*, giving out the optimum results and alternative results by weighing each solution.

6.1.1.7 2D Drawing Designer

This is the centre module, where the two dimensional drawing space is created. This panel will allow the designer to look and feel the roof shapes, ceiling shapes also the insulation thicknesses that should be installed per room. This is used to transform numeric or shapes into visualized form.

Integration of the Macromedia Flash MX was through "Text files", where optimum roof architecture parameters captured at the *Case Base Reasoner module* is written on to the text file. These parameters are

extracted by the Flash action scripts, which has been described in 5.0.

7.0 CASE BASE REASONNING MODULE

Case base Module is categorized into 7 main components in which each will be interacting through number of items present and the their fields. Basic Case base architecture is depicted below [10].

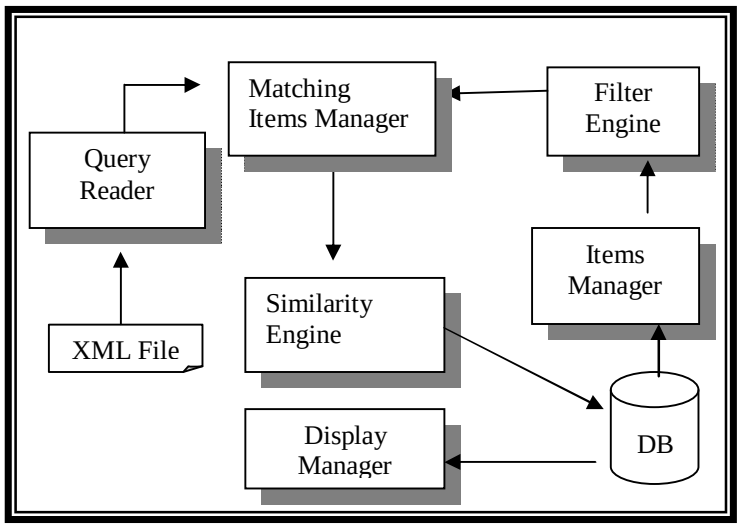


Figure 7.1 – Case base reasoning module architecture

7.1 Query Reader

This will extract the user preferences and the values specified from the XML file format. This information will be categorized into filter criteria and similar criteria .Filter criteria will be entered into the filter engine where as the similar criteria and the weights are entered in to the Matching Items Manager. Reading the XML files has been described in section 4.0.

```
<!--
Thermal Comfort Parameter -->
  <C fieldname="thermalcomfort"
Operator="<=" Value="20" />
  <C fieldname="thermalcomfort"
Operater="~" Value="28" />
  <W fieldname="thermalcomfort"
Value="7"/>
- <!--
Roof budget Filter Parameter -->
  <C fieldname="budget" Operator="<="
Value="20000" />
  <C fieldname="budget" Operator="~"
Value="65000" />
  <W fieldname="budget" Value="10" />
```

Figure 7.2 – User specified values and fields

7.2 Items Manger

This will extract past case values such as records and matches that with the user specified fields in the XML. This specific segment will hold all the case values in the database.

7.3 Filter Engine

According to the specified criteria (seen in Figure 7.2) the cases stored in the items manager are filtered by the filter engine. Along with the filtered values, filtered field names are sent to Matching items Manager.

7.4 Matching Items Manager

The filtered items obtained from the filter engine and the similar items obtained from the Query reader capture and passed to the Similarity Engine.

7.5 Similarity Engine

This segment will capture the filter items, similar items as well as their weight from the matching item manger. Using **K-nearest algorithm** [10], similarity between the filter items from the database is matched with the similar items obtain from the query reader. This will in turn calculate the distance/ similarity as a percentage. Each solution is ranked according to the percentage found.

7.6 Display Manger

Similar items gathered from the similarity engine are directly transferred to the database for easy retrieval using stored procedures created by **System.Data** and **System.Data.SQLClient** libraries.

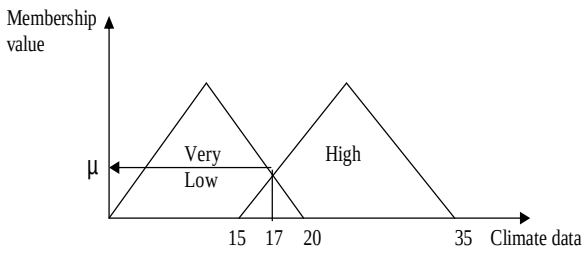
8.0 FUZZY LOGIC MODULE

The Fuzzy decider component will extract climatic data to decide on the appropriate insulation thickness for a particular room. Please note that each room will be evaluated separately in the fuzzy module.
Algorithm Used: Center of Gravity defuzzification method [16]

8.1 Fuzzifying Climatic data

When the climatic data enters in to the fuzzy module, it will check for the appropriate membership function for each climatic parameter (Room Temperature, Humidity, air velocity and Roof Temperature). Each membership function, a membership value is calculated (μ value).This value

will be passed to the inference engine with the membership name.




```
string[] theTemp =
(GetMFTempName(TempValue).Split ('|'));
// membership name
string[] theHumid=
(GetMFHumidName(HumidValue).Split('|'));
string[]
theAirVel=(GetMFAirVelName(AirVelValue).S
plit('|'));
if (theTemp.Length == 2)
   {
       TempCheck1 = theTemp[1];
       MembershipFuncnew(TempCheck1,TempValue
);  // get membership value
```

Figure 8.1 – Obtaining membership value and Membership name

8.2 Checking for the appropriate rules

The passed membership names and the values for each climatic parameter will be evaluated by running through each rule specified. Please note that each rule is generated by identifying the relationship between the climate and insulation thicknesses provided by the professionals. (E.g If Temp = High and Humidity = High and Air Velocity = Low then the interior will be uncomfortable. Therefore, thickness should be thick.) These rules will be evaluated and the appropriate rules will be fired [16].

8.3 Getting the appropriate thickness based on the climate data

Appropriate thickness membership names and the calculated membership values (μ value) will be extracted by the Inference engine procedure. Applying these values in the output membership function the appropriate thickness per room can be obtained. Using **Centre of Gravity** method, each membership function's area will be calculated and divided by the upper and lower boundaries of the total thickness membership functions to obtain the centre value. This will be deduced as the appropriate thickness value for the specified climatic data.

9.0 UNDERLYING ISSUES

In this section, some of the more important issues handled by the **"RoofOpt"** is discussed. As mentioned in 1.0, there is an argument between "designing optimum roof architecture based on thermal comfort conditions" using mathematical models and using artificial intelligence. There are a few software applications developed using AI techniques to the architectural community. This is possible only if there are predefined algorithms exist in designing roof architectures. To capture optimum results based on thermal comfort, budget etc can be obtained through professional knowledge, experience they have gain. Also it is relevant to use research/experimental results in determining the optimum solution.

In deciding the appropriate thermal insulation thickness per room according to climatic conditions is never possible using mathematical equation. Most of the manufactures have their own R-values labeled per region [11]. But, these values are not always true when a particular site location is concerned also the house architecture. Therefore, using professional knowledge experience in deciding the appropriate thicknesses per room will result in a proper solution suited for a particular dwelling.

Currently, the **RoofOpt** presents with the optimum solution by searching the highest weightage assigned by the *Case based reasoner* module. In order to automate the searching process of the optimum result among the solutions, Genetic algorithm [16] can be incorporated. We again stress the importance of obtaining the optimum results among the solutions, which is not completely automated.

10.0 IMPLEMENTATION

The [*]prototype was developed using .NET Framework in C# programming language due to its ability to create graphical designs, platform independence and powerful graphical user interfaces. SQL Server 2000 was chosen as Database Management System because of it's capability to create stored procedures to perform the transaction automatically, Optimizing application performance during data retrieval, Recovery, security etc.

"RoofOpt" is implemented in three distinct layers to support the development of three tier architecture. Because of this nature, it was able to achieve independence in each layer.
For example, changes carried out at the middle layer or at the GUI layer will not be affected on the Data

[*] For brevity, the GUI designs are not discussed in this paper. However it can be found in reference [17] for interested readers.

Layer. Here, the GUI Layer is consisting of Data Extractor, User preference Module and displaying the optimum results in three different format such as graphical, tabular and 2D designs whereas the middle layer will extract information from the GUI layer and the Data layer to perform the particular operation. The *fuzzy decider*, outputs will be directly displayed on the GUI and saves in the Database. But in the case of *Case base Reasoner*, the outputs will be directly saved in the database and retrieved by the GUI layer.

In order to decide on the appropriate insulation thickness based on the climate information captured per room, will be computed using fuzzy logic algorithm.

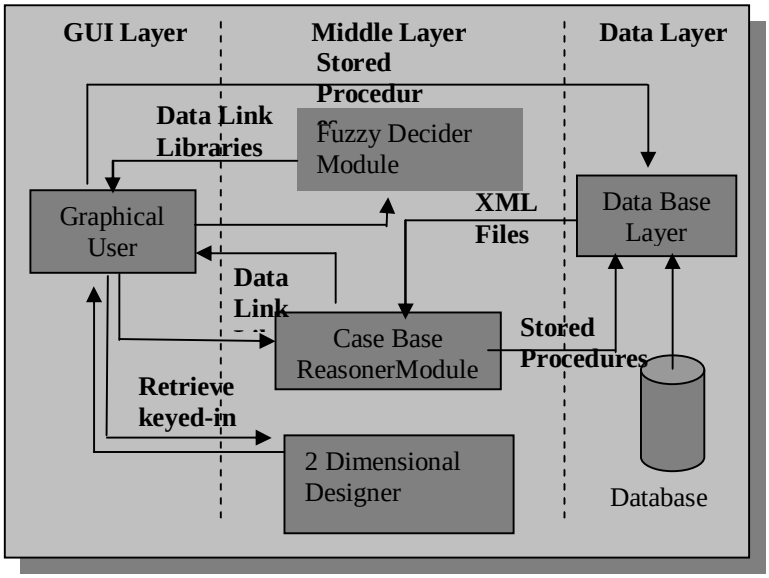


Figure 10.1 – Overall system architecture

The GUI of the prototype has the following capabilities:

- Downloading or key-in regional climatic information
- Customer Information and inquires
- Optimum roof architecture based the designed roof architecture
- Optimum roof architecture based on user requirements
- Optimum roof architecture obtained at the renovation stage of the existing building
- Insulation solution for an Existing dwelling
- Two Dimensional design portrayed for the selected optimum roof architecture

11.0 CONCLUSION

It is interesting and not altogether coincidental that this project opens up a new vista to the concept of "Thermal Comfort dwelling designs through optimum roof architecture", challenging the conventional methodologies by incorporating new technologies to tackle the problem. This project has discussed what seems to be impossible, indeed feasible and practical towards the betterment of the architectural community and relevant to most personnel attempting to tackle this problem. Many software tools exist, but most of the tools concentrate on low energy buildings, energy efficiency. Very few tools are designed to target on "Thermal comfort in dwellings" which will it turn achieve energy efficiency and cost effectiveness.

In order to address the issues on thermal discomforts, energy crisis as well as economical issues arises in third world countries, a new dwelling design tool was proposed. The unstructured, heuristic nature of the current methodologies paved the way to the proposed project "Thermal Comfort achieved in passive houses via roof architecture (RoofOpt)". This project proposes to develop an intelligent artifact which will determine the optimum roof architecture according to thermal comfort conditions in a dwelling.

The "RoofOpt" is researched in achieving a structured design method and devise a proper solution through a new design mechanism eliminating previous mathematical models. Consequently, the tool will present the optimal roof architecture and the appropriate thermal insulation thicknesses and materials for a given user specification.

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